

FW: Sediment RMS

Kofoid, Jennifer@DWR

Sent: Thursday, December 05, 2013 4:41 PM
To: DWR CWP Comments
Attachments: Vol3_Ch26_Sediment_TFB.docx (76 KB)

From: Lisa Beutler [mailto:lisa-beutler@comcast.net]
Sent: Wednesday, December 04, 2013 9:23 PM
To: Kofoid, Jennifer@DWR; Ly, Hoa@DWR
Subject: FW: Sediment RMS

For Posting

From: Challenger, Rebecca - NRCS, Davis, CA [mailto:Rebecca.Challender@ca.usda.gov]
Sent: Wednesday, November 27, 2013 9:46 AM
To: lisa-beutler@comcast.net
Subject: RE: Sediment RMS

Lisa, attached is the file with the table that includes my comments. As for the main document itself, I reread it and do not really see a discrepancy in writing style that would make it seem as if it had more than one writer. (And trust me, I have had to edit documents like that!) I think possibly the comment may be more directed to the fact that the organization of the document could be tightened up. It is complicated and is confusing to read on the screen, though I think it would be easier in paper form. That said, every document could be improved upon and much of that is more personal style choices rather than a right or wrong way of doing things. This is a complex subject matter with many ingredients thrown into one pot and you have done a great job with what you were given to work with. I am guessing much of it was frustrating at times, especially when someone new joined the group and redid what was already decided!

Maybe others will see more specific ways to address the editors' comments.

Nicely done,
Beckie

From: Lisa Beutler [mailto:lisa-beutler@comcast.net]
Sent: Friday, November 22, 2013 12:45 PM
To: GJAEQUEZ@dpw.lacounty.gov; johnkingsbury.mcwra@gmail.com; susan.m.ming@usace.army.mil; chris.potter@resources.ca.gov; jamiaa@water.ca.gov; Hopson, Rick G -FS; Hill, Barry -FS; Youngblood, Quentin -FS; George.Nichol@comcast.net; mdavis@pcwa.net; Nfeger@waterboards.ca.gov; Gyant, Barnie -FS; ccurtis@waterboards.ca.gov; Challenger, Rebecca - NRCS, Davis, CA; tara@water.ca.gov; BGreimann@usbr.gov; Clif.Davenport@conservation.ca.gov; Bruce Gwynne; Davis, Sid - NRCS, Davis, CA; STERRETT@dbw.ca.gov; Craig.S.Conner@usace.army.mil; Thomas.R.Kendall@usace.army.mil; Chris.Keithley@fire.ca.gov; Bruce Gwynne
Cc: 'Ly, Hoa@DWR'
Subject: Sediment RMS

Dear Group,

We have received the edited version of the Sediment Chapter. There are two files. One file is the pictures, tables and figures (that has the TBF extension) and the other is the word file of the chapter - it is titled PRD (stands for public review draft). We have until Dec. 6 to make edits to this file.

One of the comments from the editors was that it looked like the document had 10 authors (which I told them was

an under-estimation). Because so many of you have helped author this, I am very concerned about making changes that you have not all reviewed. Here is my proposal:

1. Please read the document between now and December 2.
2. A - You can have two options - send me your STRIKE-TEXT EDITS - in word format. That means I need you to write the text as you think it should read rather than make a comment. Please use the Strike-Text reviewers function so I can see your changes. I must receive by 3:30 p.m., Dec. 6.
AND/OR
2. B - Attend one or more of the text editing sessions I will do on-line and we will make changes real time.
3. I will POST current versions of the text with annotations on-line HERE: <http://personal.crocodoc.com/KgPP9i3>, during the week of Dec. 2 at the end of each day so you can see changes if there have been any. This will allow you to see the most recent version and agree or disagree with a change someone else has offered.
4. Our last on line session will be Dec.6 after which I will do a final proof read and turn back to the editors for layout and final on Dec. 9. If you are submitting off-line text edits I will need them PRIOR to the final editing session on 3:30 p.m. on Friday, Dec. 6.

This is the schedule for the OPTIONAL live text editing sessions:

Dec. 2, 3, 4, and 5 - 8:30-9:00 a.m. PLEASE LET ME KNOW IF YOU ARE ATTENDING ONE OF THESE LIVE EDIT SESSIONS AND I WILL SEND YOU THE MEETING PHONE AND WEB LINKS.

FINAL EDIT SESSION

Dec. 6 - 3:30 to 4:30 is the final edit session -Join on-line at

<https://www2.gotomeeting.com/join/114123922>, Join the conference call: 1-866-394-4146, Participant Code: 464650661

Thank you again to each and every one of you for this amazing collaborative effort.

Sincerely,

Lisa Beutler,

Executive Facilitator

California Water Plan Update 2013

and

Water Resources Group

MWH Americas

<<...>> <<...>>

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Table 26-1 Agency Roles and Activities in Sediment Management

TYPE	AGENCY	ROLE	SAMPLE ACTIVITES
Federal	US Department of Agriculture (USDA)	Land Managers, Advisors	Support California land management practices that incorporate erosion control and sediment management.
	Forest Service		
	Natural Resources Conservation Service)		
	Dept. of Interior (DOI)		
	Bureau of Land Management		
	US Geological Survey		
	Park Service		
Federal	Defense USACE	Regulators	Oversight for Dredging, fisheries and TMDL issues
	Dept. of Interior (DOI)		
	US Fish and Wildlife Service		
	Dept. of Commerce		
	NOAA		
Tribal	US EPA	Land Managers, Planners	Plan and manage for sediment management considerations.
	USACE		
State	Tribal Governments	Land Managers	Promotion of sediment management through best forest management practices. For over 20 years a group of advisors called the Monitoring Study Group (MSG) has, and continues, to: (1) develop a long-term program testing the effectiveness of California's Forest Practice Rules, and (2) provide guidance and oversight to the California Department of Forestry and Fire Protection (CAL FIRE) in implementing the program. The MSG has sponsored significant research on sediment management. This research informs CAL FIRE funded monitoring efforts designed to ascertain if forest practice rules, reducing unnatural sediment loads and protecting beneficial uses of water are being implemented and are effective.
	CalFIRE		
	Board of Forestry and Fire Protection (BOF)		
	State Lands Commission		
	State Parks		
State	Fish & Wildlife	Advisors	Provide significant leadership in source sediment management through the development of Best Management Practices (BMPs)
	Department of Food and Agriculture		
	Department of Conservation		
	Fish and Wildlife		
	The University of California Extension Farm Advisors		

Comment [CR-NDC1]: Activities is spelled incorrectly.

TYPE	AGENCY	ROLE	SAMPLE ACTIVITES
State	Water Boards	Regulators Training & technical Assistance	<p>Protect water quality through the issuance of regulations and permits which also serve as National Pollutant Discharge Elimination System (NPDES) permits for point source discharges subject to the Clean Water Act. Permits related to sediment control include stormwater permits for municipal stormwater systems, highways and other thoroughfares and construction activities. Permits require the implementation of best management practices (BMPs) at constructions sites, outreach and education to residents, and consideration of the principles of low impact development for redevelopment and new development sites.</p> <p>Non-point source (NPS) pollution can include sediment or pollutants carried by sediment. NPS pollution is divided into the following six categories: (1) agriculture; (2) forestry; (3) urban areas; (4) marinas and recreational boating; (5) hydromodification activities; and (6) wetlands, riparian areas, and vegetated treatment systems. The Water Boards administers grant funding to develop and implement management practices to address NPS pollution such as development and implementation of the California Rangeland Water Quality Management Plan (http://www.waterboards.ca.gov/publications_forms/publications/general/docs/ca_rangeland_wqmgmt_plan_july1995.pdf).</p> <p>Promotion of land use practices that support optimum source sediment management</p>
Regional	Sierra Nevada Conservancy	Planning Financial Assistance Training & technical Assistance	Promotion of land use practices that support optimum source sediment management
Regional	Tahoe Regional Planning Agency	Planning Regulation	Promotion of land use practices that support optimum source sediment management
Local	Local Governments, Districts, Water Agencies, Reclamation Districts and Planning Commissions	Planning Regulation	<p>Promotion of land use practices that support optimum source sediment management.</p> <p>Some local governments (city and county) support Low Impact Development (LID), including it as part of their planning and development ordinances. LID features design elements, including hydromodification, that address sedimentation at the source. Resources, including model regulations, are available to help municipalities interested in incorporating sediment source management into their planning portfolios.</p> <p>Local governments may also be involved in flood protection and water supply. (http://www.epa.gov/owow/NPS/lidnatl.pdf, http://www.epa.gov/region1/topics/water/lid.html, http://efc.muskie.usm.maine.edu/docs/lid_fact_sheet.pdf, and http://www.huduser.org/publications/pdf/practlowimpctdevel.pdf & http://www.mass.gov/envir/smart_growth_toolkit/bylaws/LID-Bylaw-reg.pdf).</p>

Comment [CR-NDC1]: Activities is spelled incorrectly.

Comment [CR-NDC2]: See comment below.

Comment [CR-NDC3]: Some of these are very long because, for example, paragraphs like this that describe what NPS is rather than what the agency actually does. I would recommend sticking to agency activities.

TYPE	AGENCY	ROLE	SAMPLE ACTIVITIES
Local	Cities Counties JPA's Commission's	Advisors	Develop a land stewardship ethic that promotes long-term sustainability of the state's rich and diverse natural resource heritage.
Local	Resource Conservation Districts	Planning, technical and financial assistance	<p>Resource Conservation Districts (RCDs) implement projects improving sediment management on public and private lands and educate landowners and the public about resource conservation. They work together to conduct:</p> <ul style="list-style-type: none"> • Watershed planning and management. • Water conservation. • Water quality protection and enhancement. • Agricultural land conservation. • Soil and water management on non-agricultural lands. • Wildlife habitat enhancement. • Wetland conservation. • Recreational land restoration. • Irrigation management. • Conservation education. • Forest stewardship. • Urban resource conservation.
NGO	California and local Farm Bureaus	Advisors Advocates	Information development and dissemination, policy advocacy
	California Rangeland Trust TNC	Training & technical Assistance	Land Holding Services
NGO	California Association of Storm Water Quality Agencies (CASQA)	Advisors Advocacy Training & technical Assistance	<p>Assists the Water Boards and municipalities throughout the state of California in implementing the National Pollutant Discharge Elimination System (NPDES) stormwater permits. One of the accomplishments of CASQA has been the development and dissemination of Best Management Practices (BMP) Handbooks. The BMPs help reduce unwanted delivery of sediment. The handbooks are designed to provide guidance to the stormwater community in California regarding BMPs for a number of activities affecting water quality and sediment management, including New Development and Redevelopment, Construction Activities, Industrial and Commercial Activities, and Municipal Activities (CASQA Web sites: http://www.casqa.org/ and http://www.cabmphandbooks.com).</p>

Comment [CR-NDC1]: Activities is spelled incorrectly.

TYPE	AGENCY	ROLE	SAMPLE ACTIVITES
Private Interests and Land Managers	PG&E, Southern California Edison and other major private utilities with large land and water holdings and infrastructure. Tejon Ranch. Irvine Ranch, etc. Timber & Rail companies (e.g. Sierra Pacific, Catellus Corporation, a successor to the Southern Pacific Land Company and affiliated with Santa Fe Pacific) Agriculture	Land Management	Pacific Forest and Watershed Lands Stewardship Council (PG&E) Irvine Ranch Conservancy Tejon Ranch Conservation and Land Use Agreement

Comment [CR-NDC1]: Activities is spelled incorrectly.

Photo 26-1 Caltrans I-5 Antlers Bridge Realignment Project on Shasta Lake

[photo to come]

Box 26-1 Debris and Sediment

The Sediment Resource Management Strategy (RMS) relates to organic materials. However sediment and debris are often comingles.

Approximately 80 percent of marine debris in the world's oceans originates from land-based sources- primarily trash and debris in stormwater and urban runoff. Studies have found that significant quantities of small plastic debris originating in urbanized land areas pollute the Pacific Ocean both near-shore and on beaches and segments of the ocean thousands of miles away from human habitation.

Studies of debris in Southern California coastal waters demonstrate that significant quantities of trash and debris originate from urban areas and are comprised of pre-production plastics from plastic industrial facilities, trash and litter from urban areas, and boating and fishing-related debris.

More about this topic may be found in the Pollution Prevention and Stormwater-Urban Run Off RMS chapters.

Source: California Coastal Commission and Algalita Marine Research Foundation, n.d.

Box 26-2 Definitions

Suspended load is the portion of the sediment that is carried by a fluid flow which settles slowly enough such that it almost never touches the bed. It is maintained in suspension by the turbulence in the flowing water and consists of particles generally of the fine sand, silt and clay size.

Bed load describes particles in a flowing fluid (usually water) that are transported along the bed of a waterway.

Wash load is the portion of sediment that is carried by a fluid flow, usually in a river, such that it always remains close the free surface (near the top of the flow in a river). It is in near-permanent suspension and is transported without deposition, essentially passing straight through the stream. The composition of wash load is distinct because it is almost entirely made up of grains that are only found in small quantities in the bed. Wash load grains tend to be very small (mostly clays & silts but some fine sands) and therefore have a small settling velocity, being kept in suspension by the flow turbulence.

Box 26-3 Case Study: Sediment Management Related to Recreational Use

Off-highway vehicle (OHV) use is a popular form of recreation in California. State and federal agencies provide recreational areas for this purpose. These OHV recreation areas need to implement a range of storm water best management practices to protect water quality. Additionally, unauthorized and unmanaged OHV areas can become erosion problems and discharge polluted storm water. With limited resources, maintaining and policing these areas can be a challenge.

In 2009, the Central Valley Water Board found that portions of the Rubicon Trail located in El Dorado County were severely eroded, erosion was accelerated by OHV use and sediment was being discharged to surface waters. (see following 3 photos provided courtesy Monte Hendricks) To address this problem as well as other OHV related water quality issues, the Central Valley Water Board issued a Cleanup and Abatement Order (Central Valley Regional Water Quality Control Board 2009) to El Dorado County and Eldorado National Forest to develop and implement plans to improve management of the trail and protect water quality.

PLACEHOLDER Photo A Rubicon Trail, U.S. Department of Agriculture Forest Service Land

PLACEHOLDER Photo B [title to come]

The Rubicon Trail Foundation, in response to criticisms over OHV use of the Rubicon Trail, has been involved in restoration activities and, in testimony to the Central Valley Water Board, provided some photos of improvements. The following three photos (also see pdf of the actual slides from the testimony to the Central Valley Water Board) show before, during and after photos of an eroded site.

In 2012, the Central Valley Water Board found that sediment disturbed by recreational vehicle activity and transported in storm water runoff to Corral Hollow Creek was a water quality problem at the Carnegie State Vehicle Recreation Area. The Board also identified metals, such as copper and lead, as a potential concern. To address these problems, the Board issued a Cleanup and Abatement Order (Central Valley Regional Water Quality Control Board 2012) to the California Department of Parks and Recreation (State Parks). The Order recognized that State Parks had developed a Storm Water Management Plan that describes the best management practices that need to be implemented to address erosion and sedimentation. The Order required State Parks to and implement the Storm Water Management Plan update.

PLACEHOLDER Photo C Off-Highway Vehicle — Sediment Settling Pond

— Betty Yee, Central Valley Regional Water Quality Board

Photo A Rubicon Trail, U.S. Department of Agriculture Forest Service Land

[photo to come]

Photo B

[title and photo to come]

Photo C Off-Highway Vehicle — Sediment Settling Pond

[photo to come]

Box 26-4 Case Study: Los Angeles County Flood Control District — Impacts of the 2009 Station Fire

In the 1800s and early 1900s, the Los Angeles Region experienced catastrophic floods that resulted in loss of life and property. Consequently, in 1915, the California State Legislature adopted the Los Angeles County Flood Control Act. The Act established the Los Angeles County Flood Control District and empowered it to provide flood risk management and conserve flood and storm waters. The Flood Control District encompasses most of Los Angeles County, including the highly erosive San Gabriel Mountains as well as other mountain ranges. The Flood Control District operates and maintains 14 dams and reservoirs, 162 debris basins, 500 miles of open channel, and other infrastructure.

Given the region's highly erosive mountains and the existing system, managing flood risk and conserving water goes hand in hand with removing and managing the sediment that accumulates at the facilities. Sediment is delivered to the facilities as a result of runoff in the mountains picking up and carrying material eroded from the mountains. The amount of sediment that reaches a facility any given year depends on the size of the watershed, the watershed's vulnerability to erosion, watershed conditions (such as vegetated watershed versus burned watershed), and weather conditions (such as amount and intensity of rain).

Wildfires greatly increase the amount of runoff and erosion from mountainous watersheds. As much as 120,000 cubic yards of sediment and debris have been produced per square mile of a burned watershed after a major storm. The first four years after a fire have proven to be the most critical in terms of the potential for increased delivery of sediment and debris to the Flood Control District's facilities. The effects of wildfires were taken into consideration during the design of the dams under the jurisdiction of the Flood Control District and continue to be considered for today's operations.

The Station Fire of 2009 was the largest fire in Los Angeles County's recorded history, burning approximately 250 square miles. The fire started on August 26th and was not fully contained until October 16th. The burned watersheds resulted in a significant increase in the amount of sediment and debris eroding from the hillsides during storms and making its way into debris basins and reservoirs. After a short but powerful burst of rain in mid-November 2009, Mullally Debris Basin, which is located in the City of La Cañada-Flintridge and has a 9,400- cubic-yard capacity, filled up in 30 minutes. There were also storms in January and February 2010 that delivered tremendous amounts of sediment to the facilities. The images shown below illustrate the amount of sediment that reached Dunsmuir and Mullally Debris Basins as a result of the Station Fire and the storms of February 2010.

PLACEHOLDER Photos A-D Dunsmuir and Mullally Debris Basins

Immediately following the Station Fire and the 2009-2010 Storm Season, a total of approximately 1.2 million cubic yards (MCY) of sediment were removed from 38 debris basins in order to reduce flood risk for the communities downstream of those debris basins from subsequent storms that still had the potential to send overtopping flows into the debris basins. In addition, many k-rails were installed in the streets of the foothill communities to direct flows away from houses in the event of debris flows due to overtopped debris basins. Emergency operations involved day and night work and trucking of sediment through neighborhoods. The total amount of sediment removed that year is the largest amount removed in any year since the Flood Control District began managing sediment accumulation in debris basins in the 1930s. Notably, the amount of sediment inflow to debris basins is small compared to the amount of sediment that impacts the reservoirs the Flood Control District maintains.

The Station Fire burned significant portions of the watersheds of four reservoirs, as listed below.

- Big Tujunga Reservoir: 88 percent of the reservoir's watershed.
- Cogswell Reservoir: 86 percent of the reservoir's watershed.
- Devil's Gate Reservoir: 68 percent of the reservoir's entire watershed, 92 percent of the reservoir's undeveloped watershed.
- Pacoima Reservoir: 80 percent of the reservoir's watershed.

Based on the Flood Control District's records, 3 of the 4 reservoirs have had an additional 1 MCY of sediment accumulate in them, as detailed in the table below. The potential for high sediment inflows into both reservoirs and debris basins will continue until the watersheds recover.

Table A [title to come]

Reservoir	Date of last survey prior to or soon after Station Fire	Date of last survey ^a	Amount accumulated between subject surveys	Challenges
Big Tujunga	October 2009	August 2011	1.6 MCY	1,2,3,5
Cogswell	December 2009	August 2011	1.7 MCY	1,2,3,5
Devil's Gate	April 2009	March 2011	1.2 MCY	4,5
Pacoima	January 2009	September 2011	0.4 MCY	1,3,4,5

^a As of June 2012

1 – Limited access ; 2 – Limited space at adjacent or nearby sediment placement sites; 3- Endangered species present downstream; 4- Conflicting environmental interests; 5- Long haul routes to facilities with available space

Another consideration at reservoirs is the amount of sediment already accumulated in them** and the capacity available for additional sediment accumulation that would not interfere with the dam's operations. Given the current volume of sediment and the high potential for large sediment inflows, the Flood Control District is planning sediment removal projects at the four reservoirs affected by the Station Fire. These projects are currently estimated to remove a total of 14 MCY of sediment over the next 8 years, with each project lasting 3 to 5 years and costing as much as \$50 million.

** Significant amounts of sediment had accumulated in the subject reservoirs prior to the Station Fire (the same is true of other reservoirs operated and maintained by the Flood Control District). This is the result of a combination of issues, including the following:

- Diverse stakeholder interests, which result in different opinions on the "best" sediment removal, transportation, and placement alternative that should be used for a project.
- Conflicting regulatory requirements.
- Restrictions from other agencies.
- Costs.

— Greg Jaquez, LA Flood Control District

Photos A-D Dunsmuir and Mullally Debris Basins

[photos to come]

Box 26-5 Case Study: California American Water Files Application for Removal of Silted-Up Dam — Dredging Not Feasible

Following is story about a proposal to remove a dam (<http://www.sandandgravel.com/news/article.asp?v1=13621>). While the San Clemente Dam no longer is providing the water supply function it was intended to meet, that may not be true for other dams in the State. For example, LA County has a lot of people (most of its 10 million population) depending on LACFCD's and Corps' dams for flood protection & water supply. This makes a discussion of sediment and dam removal essential to the water management discussion.

News - September 27, 2010

California American Water has filed an application with the California Public Utilities Commission requesting permission to remove the San Clemente Dam on the Carmel River in order to resolve seismic safety concerns associated with the dam and restore critical habitat for the steelhead trout.

"From an engineering and environmental perspective, this is a landmark project," said California American Water president Rob MacLean. "Our innovative method for dealing with the sedimentation behind the dam and the level of public-private cooperation which has made this plan a reality will serve as a template for the removal of other obsolete dams across the country."

California American Water is partnering with the National Oceanic and Atmospheric Administration's National Marine Fisheries Service and the California State Coastal Conservancy to implement the dam removal project while minimizing cost to its ratepayers. California American Water has committed \$49 million and the dedication of 928 acres where the dam is located as parkland.

The Coastal Conservancy and NOAA committed to raise the additional \$35 million needed for the removal project through a combination of public funding and private donations.

The San Clemente Dam is a 106ft high concrete-arch dam built in 1921, 18 miles from the ocean on the Carmel River, to supply water to the Monterey Peninsula's then-burgeoning population and tourism industry. Today the reservoir is over 90 percent filled with sediment and has a limited water supply function.

In 1991, the California Department of Water Resources, Division of Safety of Dams agreed with a California American Water consultant's assertion that San Clemente Dam did not meet modern seismic stability and flood safety standards.

The Department of Water Resources and Army Corps of Engineers studied many ways to ameliorate the safety issues including strengthening the dam and removing it.

The January 2008 Final Environmental Impact Report and Environmental Impact Statement ("EIR/EIS") regarding San Clemente Dam's stability contains analysis of a Reroute and Removal Project, which would address the seismic and flood safety risks associated with San Clemente Dam by permanently rerouting a portion of the Carmel River and removing the dam.

Under this proposal, the Carmel River would be rerouted to bypass the 2.5 million cubic yards of silt that have accumulated behind the dam thereby avoiding dredging, which has been deemed infeasible.

The primary benefits of the Reroute and Removal Project are that it improves the Carmel River environment by removing the dam, which serves as a barrier to fish passage, and satisfies government agencies' concerns that strengthening the dam, as opposed to removing it, could further threaten the South Central California Coast Steelhead and violate the federal Endangered Species Act.

Source: Dredging News Online 2010

Box 26-6 Case Study: Clear Lake — Algae in Clear Lake

The Clear Lake Basin was shaped by a variety of processes over the last 1 to 2 million years. Scientists have recovered a nearly continuous sequence of lake sediments dating back 475,000. Other lake sediments in the region that date back to the Early Pleistocene, approximately 1.6-1.8 million years ago.

There is an excellent climate record from these cores for the last 127,000 years. The record documents a shift from pine dominated to oak dominated forests at the end of the Pleistocene Glacial Period 10,000 years ago, indicating a warming trend. The diatom sequence in these cores indicate that Clear Lake has been a shallow, productive system, essentially similar to the modern lake since the end of the Pleistocene Period.

The basin was created primarily from the stresses of the San Andreas Fault System, the eruption and subsidence of the Clear Lake Volcanics, and the erosion and deposition of the parent rock. The east-west extension of the fault system and vertical movements of the faults created and maintained the basin. Downward vertical movement within the basin created by these processes is at a rate approximately equal to the average sedimentation rate of 1/25 inch/year in the lake basin.

Since these rates are essentially equal, a shallow lake has existed in the upper basin for at least the last 475,000 years. If sedimentation rates were significantly different from the downshift, then either a deepwater lake or a valley would have resulted. Although the lake has changed shape significantly over this period, it has generally been located in the same area as the existing Upper Arm.

Clear Lake is a naturally eutrophic lake. Eutrophic lakes are nutrient rich and very productive, supporting the growth of algae and aquatic plants (macrophytes). Factors contributing to its eutrophication include a fairly large drainage basin to contribute mineral nutrients to the water, shallow and wind mixed water, and no summertime cold water layer to trap the nutrients. Because of the lake's productivity, it also supports large populations of fish and wildlife.

The algae in Clear Lake are part of the natural food chain and keep the lake fertile and healthy. Because of the lake's relative shallowness and warm summer temperatures, the algae serve another important purpose. They keep the sun's rays from reaching the bottom, thus reducing the growth of water weeds which would otherwise choke off the lake.

Along with Clear Lake's high productivity, algae in the lake can create a situation which can be perceived as a problem to humans. Algae are tiny water plants that cycle normally between the bottom and the surface, floating up and sinking down. During the day, algae generate oxygen within the lake; at night they consume oxygen.

Nuisance blue-green algae, however, can be a problem. From more than 130 species of algae identified in Clear Lake, three species of blue-green algae can create problems under certain conditions. These problem blue-greens typically "bloom" twice a year, in spring and late summer. The intensity of the blooms vary from year to year, and are unpredictable. The problem occurs when algae blooms are trapped at the surface and die. When this occurs, unsightly slicks and odors can be produced.

It does not appear that blue-green algae are a recent development in Clear Lake.

Sediment cores collected from the bottom of Clear Lake by the United States Geological Survey (USGS) indicate Clear Lake has been eutrophic with high algal populations since the last ice age, which ended approximately 10,000 years ago. The graph at <http://www.co.lake.ca.us/Assets/WaterResources/Algae/Algae+Pollen+in+Core.pdf> shows the change in algae pollen over time from a core in the Upper Arm.

Livingston Stone, a fisheries biologist, visited Lake County in 1873 and reported to Congress that Clear Lake had significant algal populations at the time.

It is a singular fact, illustrating the inaptness with which names are often given to natural objects, that the water of Clear Lake is never clear. It is so cloudy, to use a mild word, that you cannot see three feet below the surface. The color of the water is a yellowish brown, varying indefinitely with the varying light. The water has an earthy taste, like swamp-water, and is suggestive of moss and water-plants. In fact, the bottom of the lake, except in deep places, is covered with a deep, dense moss, which sometimes rises to the surface, and often to such an extent in summer as to seriously obstruct the passage of boats through the water.

He further describes water conditions in September as:

Fish and fishing are about the same as in August. The weather is a little warmer. No one fishes during this month except the Indians, who still keep after the trout. The water this month is in its worst condition. It is full of the frothy product of the soda-springs. A green scum covers a large part of the surface, and it is not only uncleanly to look at, but unfit to drink; and yet, strangely enough, this lake, which one would think uninhabitable by fish, fairly teems and swarms with them.

These descriptions appear to describe blue-green algae and conditions similar to that in the last 20 years. The "moss" described in the first passage could be rooted plants or the filamentous algae *Lyngbya*, which behaves in a similar manner. Regardless, this moss indicates a relatively clear lake if sunlight is penetrating sufficiently to promote growth of "moss" on the bottom. The full text of Stone's writings about Clear Lake are available at <http://www.co.lake.ca.us/Assets/WaterResources/Algae/Livingston+Stone.pdf>.

Other historical accounts indicate the lake was relatively clear through 1925. Substantial declines in clarity and increases in scum forming algae (blue-green algae) occurred between 1925 and 1939. An increase in nutrient loading from increased erosion, fertilizer and wastewater discharges due to urban and agricultural development were the probable causes of increased blue-green algal growth.

The advent of powered earthmoving equipment increased the amount of soil disturbance and facilitated large construction projects, such as the Tahoe-Ukiah Highway (State Highway 20), the reclamation of the Robinson Lake floodplain south of Upper Lake, stream channelization and the filling of wetlands along the lake perimeter. To support the development, gravel mining increased within the streams, further increasing erosion and sediment delivery to Clear Lake. During this time period, mining techniques at the Sulphur Bank Mercury Mine changed from shaft mining to strip mining, resulting in the discharge of tens of thousands of yards of overburden directly into Clear Lake.

Limnological studies of Clear Lake began in the early 1960's to determine the causes of the high productivity in Clear Lake. It was found that the lake is nitrogen limited in the summer, with a great excess of phosphorus within the system. Phosphorus in the water column comes from both the annual inflows and nutrient cycling from the lake sediments. Nitrogen limitation does not affect many blue-green algae, as they were able to utilize (fix) nitrogen from the atmosphere, and consequently have an essentially unlimited supply of nitrogen. This gave these blue-green algae a competitive advantage, and *Anabaena* and *Aphanizomenon* dominated the lake during the summer. A third blue-green algae, *Microcystis*, also occurred in significant quantities. During this time period, it was also determined that iron was a limiting micro-nutrient.

Starting in the summer of 1990, lake clarity improved significantly. This improved clarity has continued until the present. The graph at <http://www.co.lake.ca.us/Assets/WaterResources/Algae/Secchi+Depth+Upper+Arm.pdf> shows the Secchi Depth (the depth into the water at which a black and white checked plate is visible) in the Upper Arm from 1969 through 2008.

During the 1991-1994 time period, University of California researchers led by Drs. Peter Richerson and Thomas Suchanek analyzed lake water quality data collected for the previous 15 years, conducted experiments and evaluated the Clear Lake system. Unfortunately, little data was available during the period of improved clarity since 1990. The "Clean Lakes Report" (<http://www.co.lake.ca.us/Assets/WaterResources/Algae/Clean+Lakes+Report+2010.pdf>) determined that excess phosphorus is a major cause, however, iron limits the growth of blue-green algae. The improved water clarity and reduced blue-green algal blooms continued into the new millennium. DWR data collected since the Clean Lakes Report was evaluated by Lake County staff in 2002. Surprisingly, phosphorus and total nitrogen concentrations in the lake did not change substantially when the lake clarity increased. cursory review of the data did not provide evidence of chemical changes that led to the improved clarity and reduced blue-green algal blooms in Clear Lake.

Source: *County of Lake 2010*